Abstract
Cataract formation is an unavoidable part of the aging process and as life expectancy increases more people will require surgery to treat cataract. Cataract surgery is very common with approximately 20 million operations performed per year worldwide. During routine cataract surgery the opaque lens of the eye is removed and replaced with an artificial lens called an intraocular lens (IOL). Current technologies used to treat cataract are highly sophisticated and the surgical operation involves remarkable skills. By contrast, the methodology used to determine the required IOL power is outdated and unsatisfactory. Currently the calculation of required IOL power is based on formulas developed from basic geometrical optics and step vergence equations combined with statistical analysis of retrospective cases. By using very accurate measurements of geometrical ocular parameters we have generated personalised eye models. These models are used to study the optimal customised IOL design for each individual eye. Such modelling reduces the reliance on approximations inherent in the current industry-standard formulas and might provide more accurate prediction of required IOL power.

History
Ridley’s first intraocular lens surgery - 1949
Kelman’s first phacoemulsification procedure - 1967
First FDA approval for an intraocular lens - 1981
Refractive surgery increases in popularity - 1990s

Intraocular lens power calculations

Geometrical optics equations - 1973

Linear regression equations - 1980

Modern formula - 1980s to 1990s

\[ P = \frac{n_{oil}}{l} - \frac{n_{oil}}{c} \times (\frac{n_{oil}}{K} - c) \]

Equation 1. The geometrical optics solution for IOL power calculation.

Equation 2. A linear regression solution for IOL power calculation.

Where P is IOL power, n is refractive index, l is axial length, K is corneal power, c is the IOL axial depth, and A is a constant specific to the IOL design and the set of surgical conditions.

The refractive surgery era

During the 1990s the popularity of refractive surgery increased significantly. This group of patients having undergone previous refractive surgery is increasing, and more of these patients are now reaching an age requiring cataract surgery. This group possesses unusual biometry values with significant amounts of higher-order aberrations (HOAs). Required IOL power for this group of patients is poorly predicted by standard methods.

IOL metrology

- Interferometry on the specific intraocular lens (Twyman-Green configuration)
- Segmented axial length (Low coherence reflectometry)
- Perform surface metrology for the specific IOL implant design.

Blometry data summary
137 subjects enrolled (48 males, 89 females), 250 valid eyes considered suitable.
Age range: 32 to 98 years (mean 75 years)
Review period: 10 to 164 days (mean 37 days)

Predicting IOL implantation depth

Low coherence reflectometry measurement provides segmented axial length data. The data set is analyzed by multiple linear regression of pre-surgery biometry parameters to predict the post-surgery axial depth of the implant.

Surgery-induced corneal topography changes

The corneal topography elevation data is fitted with Zernike polynomials to model the change in corneal topography with consideration given to the orientation of the surgical incision. This data is then used to predict the effects of the incision.

Personalised eye modelling on raytracing software

Personalised eye modeling is an essential tool for investigations of next-generation IOL designs such as those proposed to correct higher-order aberrations of the eye including coma and spherical aberration.

Conclusions
It is early in the development of personalised eye modelling and customised intraocular lens designs. Advancements in modern biometry instruments allow accurate measurement of key parameters. This methodology may be beneficial for typical cataract surgery patients as well as those with extreme ocular parameters.